The neural network circuit **25** recognizes the seated-state of a passenger A by training as described in several books on Neural Networks referenced in the above referenced patents and patent applications. Then, after training the seated-state of the passenger A and developing the neural network weights, the system is tested. The training procedure and the test procedure of the neural network circuit **25** will hereafter be described with a flowchart shown in FIG. **6**.

As diagrammed in FIG. **6**, the first step is to mount the four sets of ultrasonic sensor systems **11–14**, the weight sensors **6** and **7**, the reclining angle detecting sensor **9**, and the seat track position detecting sensor **10** into a vehicle (step S 1). Next, in order to provide data for the neural network circuit **25** to learn the patterns of seated states, data is recorded for patterns of all possible seated states and a list is maintained recording the seated states for which data was acquired. The data from the sensors/transducers **6**, **7**, **9–14** and **31–33**, for a particular occupancy of the passenger seat is called a vector (step S 2). It should be pointed out that the use of the reclining angle detecting sensor **9**, seat track position detecting sensor **10**, heart beat sensor **31**, capacitive sensor **32** and motion sensor **33** are not essential to the detecting apparatus and method in accordance with the invention. However, each of these sensors, in combination with any one or more of the other sensors enhances the evaluation of the seated-state of the seat.

For the vectors of data, adults and children each with different postures, states of windows etc. within the passenger compartment, and occupied and unoccupied child seats were selected. The selected adults include people with a variety of different physiques such as fat, lean, small, large, tall, short, and glasses wearing persons. The selected children ranged from an infant to a large child (for example, about 14 year old). In addition, the selected postures include, for example, a sitting state with legs crossed on a seat, a sitting state with legs on an instrument panel, a sitting state while reading a newspaper, a book, or a map, a sitting state while holding a cup of coffee, a cellular telephone or a dictation machine, and a slouching state with and without raised knees. Furthermore, the selected compartment states include variations in the seat track position, the window-opening amount, headrest position, and varying positions of a sun-visor. Moreover, a multitude of different models of child seats are used in the forward facing position and, where appropriate, in a rear facing position. The range of weights and the corresponding normalized values are as follows:

Class	Weight Range	Normalized Value
Empty seat	0 to 2.2 lbs.	0 to 0.01
Rear Facing Child Seat	2.2 to 60 lbs.	0.01 to 0.27
Forward facing Child Seat	2.2 to 60 lbs.	0.01 to 0.27
Normal Position Adult	60 lbs and greater	0.27 to 1

Obviously, other weight ranges may also be used in accordance with the invention and each weight range may be tailored to specific conditions, such as different vehicles. The output of the weight sensors may not correspond directly to be weight ranges in the above table. If for example strain measuring sensors are placed on each of the vehicle seat supports, such sensors will also respond to the weight of the seat itself. That weight must therefore the remove so that only the additional weight of an occupying item is measured. Similarly it may be desirable to place strain sensing devices on only some of the vehicle seat support structures. In such cases the weight of the occupying item can be in inferred from the output of the strain sensing sensors. This will be described in greater detail below.

Various vehicle setups were prepared by a combination of these variations and, for in this embodiment, almost 500,000 or more vectors should be prepared for the patterns to be used as data for the neural network training.

Next, based on the training data from the reflected waves of the ultrasonic sensor systems **11–14** and the other sensors **6**, **7**, **31–33**, the vector data is collected (step S 3). Next, the reflected waves P1–P4 are removing the initial reflected waves with a short reflection time from an object (range gating) (period T1 in FIG. 5) and the last portion of the reflected waves with a long reflection time from an object (period P2 in FIG. 5) (step S 4). It is believed that the reflected waves with a short reflection time from an object is a due to cross-talk, that is, waves from the transmitters which leaks into each of their associated receivers ChA–ChD. It is also believed that the reflected waves with a long reflection time are reflected waves from an object far away from the passenger seat or from multipath reflections. If these two reflected wave portions are used as data, they will add noise to the training process. Therefore, these reflected wave portions are eliminated from the data.

As shown in FIG. 7(*a*), measured data is normalized by making the peaks of the reflected wave pulses P1–P4 equal (step S 5). This eliminates the effects of different reflectivities of different objects and people depending on the characteristics of their surfaces such as their clothing Data from the weight sensor, seat track position sensor and seat reclining angle sensor are also frequently normalized based typically on fixed normalization parameters.

Therefore, the normalized data from the ultrasonic transducers the seat track position detecting sensor **10**, the reclining angle detecting sensor **9**, from the weight sensor(s) **6** and **7**, from the heart beat sensor **31**, the capacitive sensor **32** and the motion sensor **33** are input to the neural network circuit **25**, and the neural network circuit **25** is then trained on this data. More specifically, the neural network circuit **25** adds up the normalized data from the ultrasonic transducers, from the seat track position detecting sensor **10**, from the reclining angle detecting sensor **9**, from the weight sensor(s) **6** and **7**, from the heart beat sensor **31**, from the capacitive sensor **32** and from the motion sensor **33** with each data point multiplied by a associated weight according to the conventional neural network process to determine correlation function (step S 6).

In this embodiment, 144 data points are appropriately interconnected at 25 connecting points of layer **1**, and each data point is mutually correlated through the neural network training and weight determination process. The 144 data points consist of **138** measured data points from the ultrasonic transducers, the data (139th) from the seat track position detecting sensor **10**, the data (140th) from the reclining angle detecting sensor **9**, the data (141st) from the weight sensor(s) **6**, the data (142^{nd}) from the heart beat sensor **31**, the data (143^{rd}) capacitive sensor and the data (144^{th}) from the motion sensor. Each of the connecting points of the layer **1** has an appropriate threshold value, and if the sum of measured data exceeds the threshold value, each of the connecting points will output a signal to the connecting points of layer **2**. Although the weight sensor input is shown as a single input, in general there will be a separate input from each weight sensor used. For example, if we the seat has four seat supports and if a strained measuring element is used on each support, what will be four data inputs to neural network. The connecting points of

the layer 2 comprises 20 points, and the 25 connecting points of the layer 1 are appropriately interconnected as the connecting points of the layer 2. Similarly, each data is mutually correlated through the training process and weight determination as described above and in the above referenced neural network texts. Each of the 20 connecting points of the layer 2 has an appropriate threshold value, and if the sum of measured data exceeds the threshold value, each of the connecting points will output a signal to the connecting points of layer 3.

The connecting points of the layer 3 comprises 3 points, and the connecting points of the layer 2 are interconnected at the connecting points of the layer 3 so that each data is mutually correlated as described above. If the sum of the outputs of the connecting points of layer 2 exceeds a threshold value, the connecting points of the latter 3 will output Logic values (100), (010), and (001) respectively, for example.

The threshold value of each connecting point is determined by multiplying weight coefficients and summing up the results in sequence, and the aforementioned training process is to determine a weight coefficient Wj so that the threshold value (ai) is a previously determined output.

$$ai=\Sigma Wj \cdot Xj(j=1 \text{ to } N)$$

wherein

Wj is the weight coefficient,

Xj is the data and

N is the number of samples.

Based on this result of the training, the neural network circuit 25 generates the weights for the coefficients of the correlation function or the algorithm (step S 7).

At the time the neutral network circuit 25 has learned a suitable number of patterns of the training data, the result of the training is tested by the test data. In the case where the rate of correct answers of the seated-state detecting unit based on this test data is unsatisfactory, the neural network circuit is further trained and the test is repeated. In this embodiment, the test was performed based on about 600,000 test patterns. When the rate of correct test result answers was at about 98%, the training was ended.

The neural network circuit 25 has outputs 25*a*, 25*b* and 25*c*. Each of the outputs 25*a*, 25*b* and 25*c* outputs a signal of logic 0 or 1 to a gate circuit or algorithm 30. Based on the signals from the outputs 25*a*, 25*b* and 25*c*, any one of these combination (100), (010) and (001) is obtained. In another preferred embodiment, all data for the empty seat was removed from the training set and the empty seat case was determined based on the output of the weight sensor alone. This simplifies the neural network and improves its accuracy.

In this embodiment, the output (001) correspond to a vacant seat, a seat occupied by an inanimate object or a seat occupied by a pet (VACANT), the output (010) corresponds to a rear facing child seat (RFCS) or an abnormally seated passenger (ASP), and the output (100) corresponds to a normally seated passenger (NSP) or a forward facing child seat (FFCS).

The gate circuit (seated-state evaluation circuit) 30 can be implemented by an electronic circuit or by a computer algorithm by those skilled in the art and the details will not be presented here. The function of the gate circuit 30 is to remove the ambiguity that sometimes results when ultrasonic sensors and seat position sensors alone are used. This ambiguity is that it is sometimes difficult to differentiate between a rear facing child seat (RFCS) and an abnormally seated passenger (ASP), or between a normally seated passenger (NSP) and a forward facing child seat (FFCS). By the addition of one or more weight sensors in the function of acting as a switch when the weight is above or below 60 lbs., it has been found that this ambiguity can be eliminated. The gate circuit therefore takes into account the output of the neural network and also the weight from the weight sensor (s) as being above or below 60 lbs, and thereby separates the two cases just described and results in five discrete outputs.

Thus, the gate circuit 30 fulfills a role of outputting five kinds of seated-state evaluation signals, based on a combination of three kinds of evaluation signals from the neural network 25 and superimposed information from the weight sensor(s). The five seated-state evaluation signals are input to an airbag deployment determining circuit that is part of the airbag system and will not be described here. Naturally, as disclosed in the above reference patents and patent applications, the output of this system can also be used to activate a variety of lights or alarms to indicate to the operator of the vehicle the seated state of the passenger. Naturally, the system that has been here described for the passenger side is also applicable for the most part for the driver side.

In this embodiment, although the neural network circuit 25 has been employed as an evaluation circuit, the mapping data of the coefficients of a correlation function may also be implemented or transferred to a microcomputer to constitute the valuation circuit (see Step S 8 in FIG. 6).

According to the seated-state detecting unit of the present invention, the identification of a vacant seat (VACANT), a rear facing child seat (RFCS), a forward facing child seat (FFCS), a normally seated adult passenger (NSP), an abnormally seated adult passenger (ASP), can be reliably performed. Based on this identification, it is possible to control a component, system or subsystem in the vehicle. For example, a regulation valve which controls the inflation or deflation of an airbag may be controlled based on the evaluated identification of the occupant of the seat. This regulation valve may be of the digital or analog type. A digital regulation valve is one that is in either of two states, open or closed. The control of the flow is then accomplished by varying the time that the valve is open and closed, i.e., the duty cycle.

Moreover, the seated-slate detecting unit described above may be used in a component adjustment system and method described below when the presence of a human being occupying the seat is detected.

The component adjustment system and methods in accordance with the invention automatically and passively adjust the component based on the morphology of the occupant of the seat. As noted above, the adjustment system may include the seated-state detecting unit described above so that it will be activated if the seated-state detecting unit detects that an adult or child occupant is seated on the seat, i.e., the adjustment system will not operate if the seat is occupied by a child seat, pet or inanimate objects. Obviously, the same system can be used for any seat in the vehicle including the driver seat and the passenger seat(s). This adjustment system may incorporated the same components as the seated-state detecting unit described above, i.e., the same components may constitute a part of both the seated-state detecting unit and the adjustment system, e.g., the weight measuring means.

The adjustment system described herein, although improved over the prior art, will at best be approximate since two people, even if they are identical in all other respects, may have a different preferred driving position or other

preferred adjusted component location or orientation. A system that automatically adjusts the component, therefore, must learn from its errors, Thus, when a new occupant sits in the vehicle, for example, the system automatically estimates the best location of the component for that occupant and moves the component to that location, assuming it is not already at the best location. If the occupant changes the location, the system must remember that change and incorporate it into the adjustment the next time that person enters the vehicle and is seated in the same seat. Therefore, the system need not make a perfect selection the first time but it must remember the person and the position the component was in for that person. The system, therefore, makes one, two or three measurements of morphological characteristics of the occupant and then adjusts the component based on an algorithm. The occupant will correct the adjustment and the next time that the system measures the same measurements for those measurement characteristics, it will set the component to the corrected position. As such, preferred components for which the system in accordance with the invention is most useful are those which affect a driver of the vehicle and relate to the sensory abilities of the driver, i.e., the mirrors, the seat, the steering wheel and steering column and accelerator, clutch and brake pedals.

The first characteristic used is a measurement of the height of the occupant from the vehicle seat. This can be done by a sensor in the ceiling of the vehicle but this becomes difficult since, even for the same seat location, the head of the occupant will not be at the same angle with respect to the seat and therefore the angle to a ceiling-mounted sensor is in general unknown at least as long as only one ceiling mounted sensor is used. This problem can be solved if two or three sensors are used as described in more detail below. The simplest implementation is to place the sensor in the seat. In the '320 patent mentioned above, a rear impact occupant protection apparatus is disclosed which uses sensors mounted within the headrest. This same system can also be used to measure the height of the occupant from the seat and thus, for no additional cost assuming the rear impact occupant protection system described in the '320 patent is provided, the first measure of the occupant's morphology an be achieved. For some applications, this may be sufficient since it is unlikely that two operators will use the vehicle who have the same height. For other implementations, one or more additional measurements are used. Referring now to FIG. **8**, an automatic adjustment system for adjusting a seat (which is being used only as n example of a vehicle component) is shown generally at **100** with a movable headrest **111** and ultrasonic sensor **120** and ultrasonic receiver **121** for measuring the height of the occupant of the seat. Power means such as motors **191**, **192**, and **193** connected to the seat for moving the base of the seat, control means such as a control circuit, system or module **150** connected to the motors and a headrest actuation mechanism using servomotors **160** and **170**, which may be servomotors, are also illustrated. The seat **110** and headrest **111** are shown in phantom. Vertical motion of the headrest **111** is accomplished when a signal is sent from control module **150** to servomotor **160** through a wire **131**. Seromotor **160** rotates lead screw **162** which engages with a threaded hole in member **164** causing it to move up or down depending on the direction of rotation of the lead screw **162**. Headrest support rods **165** and **166** are attached to member **164** and cause the headrest **111** to translate up or down with member **164**. In this manner, the vertical position of the headrest can be controlled as depicted by arrow A—A. Ultrasonic transmitter and receiver **120**,**121** may be replaced by other appropriate wave-generating and receiving devices, such as electromagnetic, active infrared transmitters and receivers.

Wire **132** leads from control module **150** to servomotor **170** which rotates lead screw **172**. Lead screw **172** engages with a threaded hole in shaft **173** which is attached to supporting structures within the seat shown in phantom. The rotation of lead screw **172** rotates servo motor support **161**, upon which servomotor **160** is situated, which in turn rotates headrest support rods **165** and **166** in slots **168** and **169** in the seat **110**. Rotation servomotor support **161** is facilitated by a rod **171** upon which the servo motor support **161** is positioned. In this manner, the headrest **111** is caused to move in the fore and aft direction as depicted by arrow B—B. Naturally there are other designs which accomplish the same effect in moving the headrest up and down and fore and aft.

The operation of the system is as follows. When an adult or child occupant is seated on a seat containing the headrest and control system described above as determined by the neural network circuit **25**, the ultrasonic transmitter **120** emits ultrasonic energy which reflects off of the head of the occupant and is received by receiver **121**. An electronic circuit in control module **150** contains a microprocessor which determines the distance from the head of the occupant based on the time between the transmission and reception of an ultrasonic pulse. Control module **150** may be within the same microprocessor as neural network circuit **25** or separate therefrom. The headrest **111** moves up and down until it finds the top of the head and then the vertical position closest to the head of the occupant and then remains at that position. Based on the time delay between transmission and reception of an ultrasonic pulse, the system can also determine the longitudinal distance from the headrest to the occupant's head. Since the head may not be located precisely in line with the ultrasonic sensors, or the occupant may be wearing a bat, coat with a high collar, or may have a large hairdo, there may be some error in this longitudinal measurement.

When an occupant sits on seat **110**, the headrest **111** moves to find the top of the occupant's head as discussed above. This is accomplished using an algorithm and a microprocessor which is part of control circuit **150**. The headrest **111** then moves to the optimum location for rear impact protection as described in the above referenced '320 patent. Once the height of the occupant has been measured, another algorithm in the microprocessor in control circuit **150** compares the occupant's measured height with a table representing the population as a whole and from this table, the appropriate positions for the seat corresponding to the occupant's height is selected. For example, if the occupant measured 33 inches from the top of the seat bottom, this might correspond to a 85% human, depending on the particular seat and statistical tables of human measurements.

Careful study of each particular vehicle model provides the data for the table of the location of the seat to properly position the eyes of the occupant within the "eye-ellipse", the steering wheel within a comfortable reach of the occupant's hands and the pedals within a comfortable reach of the occupant's feet, based on his or her size, etc.

Once the proper position has been determined by control circuit **150**, signals are sent to motors **191**, **192**, and **193** to move the seat to that position. If during some set time period after the seat has been positioned, the operator changes these adjustments, the new positions of the seat are stored in association with an occupant height class in a second table within control circuit **150**. When the occupant again occu-

pies the seat and his or her height has once again been determined, the control circuit will find an entry in the second table which takes precedence over the basic, original table and the seat returns to the adjusted position. When the occupant leaves the vehicle, or even when the engine is shut off and the door opened, the seat can be returned to a neutral position which provides for easy entry and exit from the vehicle.

The seat **110** also contains two control switch assemblies **180** and **182** for manually controlling the position of the seat **110** and headrest **111**. The seat control switches **180** permit the occupant to adjust the position of the seat if he or she is dissatisfied with the position selected by the algorithm. The headrest control switches **182** permit the occupant to adjust the position of the headrest in the event that the calculated position is uncomfortably close to or far from the occupant's head. A woman with a large hairdo might find that the headrest automatically adjusts so as to contact her hairdo. This adjustment she might find annoying and could then position the headrest further from her head. For those vehicles which have a seat memory system for associating the seat position with a particular occupant, which has been assumed above, the position of the headrest relative to the occupant's head could also be recorded. Later, when the occupant enters the vehicle, and the seat automatically adjusts to the recorded preference the headrest will similarly automatically adjust (FIG. **17B**).

The height of the occupant, although probably the best initial morphological characteristic, may not be sufficient especially for distinguishing one driver from another when they are approximately the same height. A second characteristic, the occupant's weight, can also be readily determined from sensors mounted within the seat in a variety of ways as shown in FIG. **9** which is a perspective view of the seat shown in FIG. **8** with a displacement or weight sensor **200** shown mounted onto the seat. Displacement sensor **200** is supported from supports **202** and **204**. Referring now to FIG. **9A**, which is a view of the apparatus of FIG. **9** taken along line **9A—9A**, seat **230** is constructed from a foam layer **232** which is supported by a spring system **234** which is in contract with the displacement sensor **200**. The displacement sensor **200** comprises an elongate cable **205** retained at one end by support **210** and a displacement sensor **220** situated at an opposite end. This displacement sensor **220** can be any of a variety of such devices including, but not limited to, a linear rheostat, a linear variable differential transformer (LVDT), a linear variable capacitor, or any other length measuring device. Alternately, the cable can be replaced with a spring and the tension in the spring measured using a strain gage or other force measuring device or the strain in the seat support structure can be measured by appropriately placing strain gages on one or more of the seat supports as described in more detail below. One seat design is illustrated in FIG. **9**. Similar weight measurement systems can be designed for other seat designs. Also, some products are available which can approximately measure weight based on pressure measurements made at or near the upper seat surface **236**. It should be noted that the weight measured here will not be the entire weight of the occupant since some of the occupant's weight will be supported by his or her feet which are resting on the floor or pedals. As noted above, the weight may also be measured by the weight sensor(s) **6** and **7** described above in the seated-state detecting unit.

As weight is placed on the seat surface **236**, it is supported by spring **234** which deflects downward causing cable **205** of the sensor **200** to begin to stretch axially. Using a LVDT

as an example of length measuring device **220** the cable **205** pulls on rod **221** tending to remove rod **221** from cylinder **223** (FIG. **9B**). The movement of rod **221** out of cylinder **223** is resisted by a spring **222** which returns the rod **221** into the cylinder **223** when the weight is removed from the seat surface **236**. The amount which the rod **221** is removed from the cylinder **223** is measured by the amount of coupling between the windings **226** and **227** of the transformer as is well understood by those skilled in the art. LVDT's are commercially available devices. In this matter, the deflection of the seat can be measured which is a measurement of the weight on the seat. The exact relationship between weight and LVDT output is generally determined experimentally for this application.

By use of a combination of weight and height, the driver of the vehicle can in general be positively identified among the class of drivers who operate the vehicle. Thus, when a particular driver first uses the vehicle, the seat will be automatically adjusted to the proper position. If the driver changes that position within a prescribed time period, the new seat position will be stored in the second table for the particular driver's height and weight. When the driver reenters the vehicle and his or her height and weight are again measured, the seat will go to the location specified in the second table if one exists. Otherwise, the location specified in the first table will be used.

This system provides an identification of the driver based on two morphological characteristics which is adequate for most cases. As additional features of the vehicle interior identification and monitoring system described in the above referenced patent applications are implemented, it will be possible to obtain additional morphological measurements of the driver which will provide even greater accuracy in driver identification. Two characteristics may not be sufficient to rely on for theft and security purposes, however, many other driver references can still be added to seat position with this level of occupant recognition accuracy. These include the automatic selection of a preferred radio station, vehicle temperature, steering wheel and steering column position, etc.

One advantage of using only the height and weight is that it avoids the necessity of the seat manufacturer from having to interact with the headliner manufacturer, or other component suppliers, since all of the measuring transducers are in the seat. This two characteristic system is generally sufficient to distinguish drivers that normally drive a particular vehicle. This system costs little more than the memory systems now in use and is passive, i.e., it does not require action on the part of the occupant after his initial adjustment has been made.

Instead of measuring the height and weight of the occupant, it is also possible to measure a combination of any two morphological characteristics and during a training phase, derive a relationship between the occupancy of the seat, e.g., adult occupant, child occupant, etc, and the data of the two morphological characteristic. This relationship may be embodied within a neural network so that during use, by measuring the two morphological characteristics, the occupancy of the seat can be determined.

Naturally, there are other methods of measuring the height of the driver such as placing the transducers at other locations in the vehicle. Some alternatives are shown in FIG. **10** which is a side plan view wherein two height measuring sensors **320**, **321** are shown, sensor **321** being mounted into the headliner above the occupant's head and the other sensor **320** being mounted onto the A-pillar. A sensor as used herein is the combination of two transducers (a transmitter and a

receiver) or one transducer which can both transmit and receive. The headliner is the trim which provides the interior surface to the roof of the vehicle and the A-pillar is the roof-supporting member which is on either side of the windshield and on which the front doors are hinged. These transducers may already be present because of other implementations of the vehicle interior identification and monitoring system described in the above referenced patent applications. In this case, the use of both transducers provides a more accurate determination of location of the head of the driver. Using transducer **321** alone, the exact position of the head is ambiguous since the transducer measures the distance to the head regardless of what direction the head is. By knowing the distance from the head to transducer **320** the ambiguity is substantially reduced. This argument is of course dependent on the use of ultrasonic transducers. Optical transducers using CCD or CMOS arrays are now becoming price competitive and, as pointed out in the above referenced patent applications, will be the technology of choice for interior vehicle monitoring. A single CCD array of 160 by 160 pixels, for example, coupled with the appropriate pattern recognition software, can be used to form an image of the head of an occupant and accurately locate the head for the purposes of this invention.

FIG. **10** also illustrates a system where the seatbelt **330** has an adjustable upper anchorage point **331** which is automatically adjusted by a motor **332** to a location optimized based on the height of the occupant. The calculations for this feature and the appropriate control circuitry can also be located in control module **301** or elsewhere if appropriate.

Many luxury automobiles today have the ability to control the angle of the seat back as well as a lumbar support. These additional motions of the seat can also be controlled by the seat adjustment system in accordance with the invention. FIG. **11** is a view of the seat of FIG. **8** showing motors **481** and **482** for changing the tilt of the seat back and the lumbar support. Three motors **482** are used to adjust the lumbar support in this implementation. The same procedure is used for these additional motions as described for FIG. **8** above.

An initial table is provided based on the optimum positions for various segments of the population. For example, for some applications the table may contain a setting value for each five percentile of the population for each of the 6 possible seat motions fore and aft, up and down, total seat tilt, seat back angle, lumbar position, and headrest position for a total of 120 table entries. The second table similarly would contain the personal preference modified values of the 6 positions desired by a particular driver.

In FIG. **8**, the ultrasonic transducers **120** and **121** were described as one being a transmitter and the other being a receiver. For some applications, it is desirable to use both transducers as both transducers and receivers. Similarly, a third combination transmitter and receiver **122** may also be utilized as shown in FIG. **11**. This arrangement permits many of the advantages of a phased array system to be achieved.

The angular resolution of a transducer is proportional to the ratio of the wavelength to the diameter of the transmitter. Once three transmitters and receivers are used, the approximate equivalent single transmitter and receiver is one which has a diameter approximately equal to the shortest distance between any pair of transducers. In this case, the equivalent diameter is equal to the distance between transmitter **120** or **121** and **122**. This provides far greater resolution and, by controlling the phase between signals sent by the transmitters, the direction of the equivalent ultrasonic beam can be controlled. Thus, the head of the driver can be scanned with great accuracy and a map made of the occupant's head. Using this technology plus an appropriate pattern recognition algorithm, such as a neutral network, an accurate location of the driver's head can be found even when the driver's head is partially obscured by a hat, coat, or hairdo. This also provides at least one other identification morphological characteristic which can be used to further identify the occupant, namely the diameter of the driver's head.

With a knowledge of the weight of an occupant, additional improvements can be made to automobile and truck seat designs. In particular, the stiffness of the seat can be adjusted so as to provide the same level of comfort for light and for heavy occupants. The damping of occupant motions, which heretofore has been largely neglected, can also be readily adjusted as shown on FIG. **12** which is a view of the seat of FIG. **8** showing one of several possible arrangements for changing the stiffness and the damping of the seat. In the seat bottom **520** there is a container **515**, the conventional foam and spring design has been replaced by an inflated rectangular container very much like an air mattress which contains a cylindrical inner container **518** which is filled with an open cell urethane foam. An adjustable orifice **525** connects the two container **515**,**518** so that air can flow in a controlled manner therebetween. The amount of opening of orifice **525** is controlled by control circuit **150**. A small air compressor **555** controls the pressure in container **515** tinder control of the control circuit **150**. A pressure transducer **560** monitors the pressure within container **515** and inputs this information into control circuit **150**.

The operation of the system is as follows. When an occupant sits on the seat, pressure initially builds up in the seat container **515** which gives an accurate measurement of the weight of the occupant. Control circuit **150** using an algorithm and a microprocessor, then determines an appropriate stiffness for the seat and adds pressure to achieve that stiffness. The pressure equalizes between the two containers **515** and **518** through the flow of air through orifice **525**. Control circuit **150** also determines an appropriate damping for the occupant and adjusts the orifice **525** to achieve that damping. As the vehicle travels down the road and the road roughness causes the seat to move up and down, the inertial force on the seat by the occupant causes the air pressure to rise and fall in container **518** and also, but, much less so, in container **515** since the occupant sits mainly above container **518** and container **515** is much larger than container **518**. The major deflection in the seat takes place first in container **518** which pressurizes and transfers air to container **515** through orifice **525**. The size of the orifice opening determines the flow rate between the two containers and therefore the damping of the motion of the occupant. Since this opening is controlled by control circuit **150** the amount of damping can thereby also be controlled. Thus, in this simple structure, both the stiffness and damping can be controlled to optimize the seat for a particular driver. Naturally, if the driver does not like the settings made by control circuit **150** he or she can change them to provide a stiffer or softer ride.

The stiffness of a seat is the change in force divided by the change in deflection. This is important for many reasons, one of which is that it controls the natural vibration frequency of the seat occupant combination. It is important that this be different from the frequency of vibrations which are transmitted to the seat from the vehicle in order to minimize the up and down motions of the occupant. The damping is a force which opposes the motion of the occupant and which is dependent on the velocity of relative motion between the occupant and the seat bottom. It thus removes energy and

minimizes the oscillatory motion of the occupant. These factors are especially important in trucks where the vibratory motions of the driver's seat, and thus the driver, have caused many serious back injuries among truck drivers.

In an automobile, there is an approximately fixed vertical distance between the optimum location of the occupant's eyes and the location of the pedals. The distant from a driver's eyes to his or her feet, on the other hand, is not the same for all people. An individual driver now compensates for this discrepancy by moving die seat and by changing the angle between his or hers legs and body. For both small and large drivers, this discrepancy cannot be fully compensated for and as a result, their eyes are not appropriately placed. A similar problem exists with the steering wheel. To help correct these problems, the pedals and steering column should be movable as illustrated in FIG. **13** which is a plan view similar to that of FIG. **10** showing a driver and driver seat with an automatically adjustable steering column and pedal system which is adjusted based on the morphology of the driver. In FIG. **13**, a motor **650** is connected to and controls the position of the steering column and another motor **660** is connected to and controls the position of the pedals. Both motors **650,660** are coupled to and controlled by control circuit **150** wherein now the basic table of settings includes values for both the pedals and steering column locations.

As various parts of the vehicle interior identification and monitoring system described in the above reference patent applications are implemented, a variety of transmitting and receiving transducers will be present in the vehicle passenger compartment. If several of these transducers are ultrasonic transmitters and receivers, they can be operated in a phased array manner, as described above for the headrest, to permit precise distance measurements and mapping of the components of the passenger compartment. This is illustrated in FIG. **14** which is a perspective view of the interior of the passenger compartment showing a variety of transmitters and receivers, **700–706** which can be used in a phased array system. In addition, information can be transmitted between the transducers using coded signals in a ultrasonic network through the vehicle compartment airspace. If one of these sensors is an optical CCD or CMOS array, the location of the driver's eyes can be accurately determined and the results sent to the seat ultrasonically. Obviously, many other possibilities exist.

The eye ellipse discussed above is illustrated at **810** in FIG. **15**, which is a view similar to FIG. **1**, showing the occupant's eyes and the seat adjusted to place the eyes at a particular vertical position for proper viewing through the windshield and rear view mirror. Many systems are now under development to improve vehicle safety and driving ease. For example, right vision systems are being tested which project an enhanced image of the road ahead of the vehicle onto the windshield in a "heads-up display". The main problem with the systems now being tested is that the projected image does not precisely overlap the image as seen through the windshield. This parallax causes confusion in the driver and can only be corrected if the location of the driver's eyes is accurately known. One method of solving this problem is to use the passive seat adjustment system described herein to place the occupant's eyes at the optimum location as described above. Once this has been accomplished, in addition to solving the parallax problem, the eyes are properly located with respect to the rear view mirror **820** and little if any adjustment is required in order for the driver to have the proper view of what is behind the vehicle.

Several systems are in development for determining the location of an occupant and modifying the deployment of the airbag based of his or her position. These systems are called "smart airbags". The passive seat control system in accordance with this invention can also be used for this purpose as illustrated in FIG. **16**. This figure is a view similar to FIG. **8** showing an inflated airbag **900** and an arrangement for controlling both the flow of gas into and out of the airbag during a crash. The determination is made based on height sensors **120**, **121** and **122** located in the headrest, a weight sensor **200** in the seat and the location of the seat which is known by control circuit **150** (See. FIGS. **8**. **9** and **9A**). Other smart airbags systems rely only on the position of the occupant determined from various position sensors using ultrasonics or optical sensors.

The weight sensor coupled with the height sensor and the occupant's velocity relative to the vehicle, as determined by the occupant position sensors, provides information as to the amount of energy which the airbag will need to absorb during the impact of the occupant with the airbag. This, along with the location of the occupant relative to the airbag, is then used to determine the amount of gas which is to be injected into the airbag during deployment and the size of the exit orifices which control the rate of energy dissipation as the occupant is interacting with the airbag during the crash. For example, if an occupant is particularly heavy then it is desirable to increase the amount of gas, and thus the initial pressure, in the airbag to accommodate the larger force which will be required to arrest the relative motion of the occupant. Also, the size of the exit orifices should be reduced, since there will be a larger pressure lending to force the gas out of the orifices, in order to prevent the bag from bottoming out before the occupant's relative velocity is arrested. Similarly, for a small occupant the initial pressure would be reduced and the size of the exit orifices increased. If, on the other hand, the occupant is already close to the airbag then the amount of gas injected into the airbag needs to be reduced.

There are many ways of varying the amount of gas injected into the airbag some of which are covered in the patent literature and include, for example, inflators where the amount of gas generated and the rate of generation is controllable. For example, in a particular hybrid inflator manufactured by the Allied Signal Corporation, two pyrotechnic charges are available to heat the stored gas in the inflator. Either or both of the pyrotechnic charges can be ignited and the timing between the ignitions can be controlled to significantly vary the rate of gas flow to the airbag.

The flow of gas out of the airbag is traditionally done through fixed diameter orifices placed in the bag fabric. Some attempts have been made to provide a measure of control through such measures as blowout patches applied to the exterior of the airbag. Other systems were disclosed in U.S. patent application Ser. No. 07/541,464 filed Feb. 9, 1989, now abandoned. FIG. **16A** illustrates schematically an inflator **910** generating gas to fill airbag **900** through control valve **920**. The flow of gas out of airbag **900** is controlled by exit control valve **930**. The valve **930** can be implemented in many different ways including, for example, a motor operated valve located adjacent the inflator and in fluid communication with the airbag or a digital flow control valve as discussed above. When control circuit **150** determines the size and weight of the occupant, the seat position and the relative velocity of the occupant, it then determines the appropriate opening for the exit valve **930** which is coupled to the control circuit **150**. A signal is then sent from control circuit **150** to the motor controlling this valve which provides the proper opening.

In a like manner, other parameters can also be adjusted, such as the direction of the airbag, by properly positioning the angle and location of the steering wheel relative to the driver. If seatbelt pretensioners are used, the amount of tension in the seatbelt or the force at which the seatbelt spools out, for the case of force limiters, could also be adjusted based on the occupant morphological characteristics determined by the system of this invention.

Once the morphology of the driver and the seat position is known, many other objects in the vehicle can be automatically adjusted to conform to the occupant. An automatically adjustable seat armrest, a cup holder, the cellular phone, or any other objects with which the driver interacts can be now moved to accommodate the driver. This is in addition to the personal preference items such as the radio station, temperature, etc. discussed above.

Once the system of this invention is implemented, additional features become possible such as a seat which automatically makes slight adjustments to help alleviate fatigue or to account for a change of position of the driver in the seat, or a seat which automatically changes position slightly based on the time of day. Many people prefer to sit more upright when driving at night, for example. Other similar improvements based on knowledge of the occupant morphology will now become obvious to those skilled in the art.

In the above-described component adjustment systems and methods, one of the characteristics of the occupying item that may be measured is the weight. Several non-limiting examples of weight measuring apparatus will now be described which may be used in the above-described systems and methods.

In a first embodiment of a weight measuring apparatus shown in FIG. 18, four strain gage weight sensors or transducers are used, two being illustrated at **1010** and **1011** on one side of a bracket of the support structure of the seat and the other two being at the same locations on another bracket of the support (i.e., hidden on the corresponding locations on the other side of the support). The support structure of the seat supports the seat on a substrate such as a floor pan of the vehicle. Each of the strain gage transducers **1010,1011** also contains electronic signal conditioning apparatus, e.g., amplifiers, analog to digital converters, filters etc., which is associated such that output from the transducers is a digital signal. This electronic signal travels from transducer **1010** to transducer **1011** through a wire **1020**. Similarly, wire **1021** transmits the output from transducers **1010** and **1011** to the next transducer in the sequence (one of the hidden transducers). Additionally, wire **1022** carries the output from these three transducers toward the fourth transducer (the other hidden transducer) and wire **1023** finally carries all four digital signals to an electronic control system or module **1030**. These signals from the transducers **1010,1011** are time or frequency division multiplexed as is well known in the art. The seat position is controlled by motors **1040** as described in detail in U.S. Pat. No. 5,79,576, which is included herein by reference. Finally, the seat is bolted onto the support structure through bolts not shown which attach the seat through holes **1050** in the brackets.

By placing the signal conditioning electronics, analog to digital converters, and other appropriate electronic circuitry adjacent the strain gage element, the four transducers can be daisy chained or otherwise attach together and only a single wire is required to connect all of the transducers to the control module **1030** as well as provide the power to run the transducers and their associated electronics.

The control system **1030** e.g., a microprocessor, is arranged to receive the digital signals from the transducers **1010,1011** and determine the weight of the occupying item of the seat based thereon. In other words, the signals from the transducers **1010,1011** are processed by the control system **1030** to provide an indication of the weight of the occupying item of the seat, i.e., the force exerted by the occupying item on the seat support structure.

A typical manually controlled seat structure is illustrated in FIG. 19 and described in greater detail in U.S. Pat. No. 4,285,545. The seat **1056** is attached to a pair of slide mechanisms **1058** in the rear thereof through support members such as rectangular tubular structures **1060** angled between the seat **1056** and the slide mechanisms **1058**. The front of the seat **1056** is attached to the vehicle through another support member such as a slide member **1062**, which is engaged with a housing **1064**. Slide mechanisms **1058** and slide member **1062** constitutes the support structure for mounting the seat on a substrate, i.e., the floor pan. Strain gage transducers are located for this implementation at **1065** and **1066**, strain gage transducer **1065** being mounted on each tubular structure **1060** (only one of which is shown) and strain gage transducer **1066** being mounted on slide member **1062**. When an occupying item is situated on the seat cushion (not shown), each of the support members **1060** and **1062** are deformed or strained. This strain is measured by transducers **1065** and **1066**, respectively, to enable a determination of the weight of the item occupying the seat. More specifically, a control system or module or other compatible processing unit (not shown) is coupled to the strain gage transducers **1065,1066**, e.g., via electrical wires (not shown), to receive the measured strain and utilize the measured strain to determine the weight of the occupying item of the seat.

FIG. 19A illustrates an alternate arrangement for the seat support structures wherein a gusset **1068** has been added to bridge the angle on the support. Strain gage transducer **1069** is placed on this gusset **1068**. Since the gusset **1068** is not a supporting member, it can be made considerably thinner than the seat support member **1060**. As the seat is loaded by an occupying item, the seat support member **1060** will bend. Since the gusset **1068** is relatively weak, greater strain will occur in the gusset then in the support member **1060**. The existence of this greater strain permits more efficient use of the strain gage dynamic range thus improving the accuracy of the weight measurement.

FIG. 19B illustrates a seat transverse support member **1070** of the seat shown in FIG. 19, which is situated below the base cushion and extends between opposed lateral sides of the seat. This support member **1070** will be directly loaded by the vehicle seat and thus will provide an average measurement of the force exerted or weight of the occupying item. The deflection or strain in support member **1070** is measured by a strain gage transducer **1072** mounted on the support member **1070** for this purpose. In some applications, the support member **1070** will occupy the entire space fore and aft below the seat cushion. Here it is shown as a relatively narrow member. The strain gage transducer **1072** is coupled, e.g., via an electrical wire (not shown), to a control module or other processing unit (not shown) which utilizes the measured strain to determine the weight of the occupying item of the seat.

In FIG. 19, the support members **1060** are shown as rectangular tubes. In the constructions shown in FIGS. 20A–20C, the rectangular tubular structure has been replaced by a circular tube where only be lower portion of the support is illustrated. FIGS. 20A–20C show three alternate ways of improving the accuracy of the strain gage system, i.e., the accuracy of the measurements of strain by

the strain gage transducers. In each case, the transducer is represented by **1065** and the support member corresponding to support member **1060** in FIG. **19** has been labeled **106A**. In FIG. **20A**, the tube **1060A** has been cut to thereby form two separate tubes having longitudinally opposed ends and an additional tube section **1074** has been connected, e.g., by welding, to end portions of the two tubes. In this manner, a more accurate tube section **1074** can be used to permit a more accurate measurement of the strain by transducer **1065**, which is mounted on tube section **1074**. In FIG. **20B**, a small circumferential cut has been made in tube support member **1060A**. This cut is used to control the diameter of the tube at the location where strain gage transducer **1065** is measuring the strain. In other words, the strain gage transducer **1065** is placed at a portion wherein the diameter thereof is less than the diameter of remaining portions of the tube. The purpose of this cut is to correct for manufacturing variations in the diameter of the tube **1060A**. The magnitude of the cut is selected so as to not significantly weaken the structural member but instead to control the diameter tolerance on the tube so that the strain from one vehicle to another will be the same for a particular loading of the seat. In FIG. **20C**, a small hole **1078** is made in the tube **1060A** adjacent the transducer **1065** to compensate for manufacturing tolerances on the tube **1060A**. From this discussion, it can be seen that all three techniques have as their sole purpose to increase the accuracy of the strain in the support member corresponding to weight on the vehicle seat. Naturally, the preferred approach would be to control the manufacturing tolerances on the support structure tubing so that the variation from vehicle to vehicle is minimized. For some applications where accurate measurements of weight are desired, the seat structure will be designed to optimize the ability to measure the strain in the support members and thereby to optimize the measurement of the weight of the occupying item. The inventions disclosed herein therefore, are intended to cover the entire seat when the design of the seat is such as to be optimized for the purpose of strain gage weight sensing and alternately for the seat structure when it is so optimized.

Although strain measurement devices have been discussed above, pressure measurement systems can also be used in the seat support structure to measure the weight on the seat. Such a system is illustrated in FIG. **21**. A general description of the operation of this apparatus is disclosed in U.S. Pat. No. 5,785,291, which is included herein by reference. In that patent, the vehicle seat is attached to the slide mechanism by means of bolts **1084**. Between the seat and the slide mechanism, a shock absorbing washer has been used for each bolt. In the present invention, this shock absorbing washer has been replaced by a sandwich construction consisting of two washers of shock absorbing material **1080** with a pressure sensitive material **1082** sandwiched in between. A variety of materials can be used for the pressure sensitive material **1082**, which generally work on either the capacitance or resistive change of the material as it is compressed. The wires from this material leading to the electronic control system are not shown in this view. The pressure sensitive material is coupled to the control system, e.g., a microprocessor, and provides the control system with an indication of the pressure applied by the seat oil the slide mechanism which is related to the weight of the occupying item of the seat. Generally, material **1082** is constructed with electrodes oil the opposing faces such that as the material is compressed, the spacing between the electrodes is decreased. This spacing change thereby changes both the resistive and the capacitance of the sandwich which can be measured and which is a function of the compressive force

on the material. The use of such a pressure sensor is not limited to the illustrated embodiment wherein the shock absorbing material **1080** and pressure sensitive material **1082** are placed around bolt **1084**. It is also not limited to the use or incorporation of shock absorbing material in the implementation.

In FIG. **22**, which is a view of a seat attachment structure described in U.S. Pat. No. 5,531,503, where a more conventional strain gage load cell design designated **1100** is utilized. One such load cell design **1100** is illustrated in detail in FIG. **22A**.

A cantilevered beam load cell design using a half bridge strain gage system **1110** is shown in FIG. **22A**. Fixed resistors mounted within the electronic package, which is not shown in this drawing, provide the remainder of the whetstone bridge system. The half bridge system is frequently used for economic reasons and where some sacrifice in accuracy is permissible. The load cell **110** includes a member on which the strain gage **1110** is situated. The strain gage **1100** includes strain-measuring elements **1112** and **1114** arranged on the load cell. The longitudinal element **1112** measures the tensile strain in the beam when it is loaded by the seat and its contents, not shown, which is attached to end **1122** of bolt **1120**. The load cell is mounted to the vehicle or other substrate using bolt **1130**. Temperature compensation is achieved in this system since the resistance change in strain elements **1112** and **1114** will vary the same amount with temperature and thus the voltage across the portions of the half bridge will remain the same. The strain gage **1100** is coupled to a control system (e.g., a microprocessor-not shown) via wires **1124** and receives the measured tensile strain and determines the weight of an occupying item of the seat based thereon.

One problem with using a cantilevered load cell is that it imparts a torque to the member on which it is mounted. One preferred mounting member on an automobile is the floor-pan which will support significant vertical loads but is poor at resisting torques since floor-pans are typically about 1 mm (0.04 inches) thick. This problem can be overcome through the use of a simply supported load cell design designated **1200** as shown in FIG. **22B**.

In FIG. **22B** a full bridge strain gage system **1210** is used with all four elements **1212,1214** mounted on the top of a beam **1205**. Elements **1212** are mounted parallel to the beam **1205** and elements **1214** are mounted perpendicular to it. Since the maximum strain is in the middle of the beam **1205**, strain gage **1210** is mounted close to that location. The load cell, shown generally as **1200** is supported by the floor pan, not shown, at supports **1230** that are formed by bending the beam **1205** downward at its ends. Fasteners **1220** fit through holes **1222** in the beam **1205** and serve to hold the load cell **1200** to the floor pan without putting significant forces on the load cell **1200**. Holes are provided in the floor-pan for bolt **1240** and for fasteners **1220**. Bolt **1240** is attached to the load cell **1200** through hole **1250** of the beam **1205** which serves to transfer the force from the seat to the load cell **1200**.

The electronics package is potted within hole **1262** using urethane potting compound **1244** and includes signal conditioning circuits, a microprocessor with integral ADCs **1280** and a flex circuit **1275** (FIG. **22C**). The flex circuit **1275** terminates at an electrical connector **1290** for connection to other vehicle electronics, e.g., a control system. The beam **1205** is slightly tapered at location **1232** so that the strain is constant in the strain gage.

Although thus far only beam type load cells have been described, other geometries can also be used. One such

geometry is a tubular type load cell. Such a tubular load cell is shown generally at **1300** in FIG. **22D** and instead of an elongate beam, it includes a tube. It also comprises a plurality of strain sensing elements **1310** for measuring tensile and compressive strains in the tube as well as other elements, not shown, which are placed perpendicular to the elements **1310** to provide for temperature compensation. Temperature compensation is achieved in this manner, as is well known to those skilled in the art of the use of strain gages in conjunction with a whetstone bridge circuit, since temperature changes will affect each of the strain gage elements identically and the total effect thus cancels out in the circuit. The same bolt **1340** can be used in this case for mounting the load cell to the floor-pan and for attaching the seat to the load cell.

Another alternate load cell design shown generally in FIG. **22E** as **1400** makes use of a torsion bar **1410** and appropriately placed torsional strain sensing elements **1420**. A torque is imparted to the bar **1410** by means of lever **1430** and bolt **1440** which attaches to the seat structure not shown. Bolts **1450** attach the mounting blocks **1460** at ends of the torsion bar **1410** to the vehicle floor-pan.

The load cells illustrated above are all preferably of the foil strain gage type. Other types of strain gages exist which would work equally which include wire strain gages and strain gages made from silicon. Silicon strain gages have the advantage of having a much larger gage factor and the disadvantage of greater temperature effects. For the high-voltage implementation of this invention, silicon strain gages have an advantage in that the electronic circuitry (signal conditioning, ADCs, etc.) can be integrated with the strain gage for a low cost package. Other strain gage materials and load cell designs may, of course, be incorporated within the teachings of this invention.

Many seat designs have four attachment points for the seat structure to attach to the vehicle. Since the plane of attachment is determined by three points, the potential exists for a significant uncertainty or error to be introduced. This problem can be compounded by the method of attachment of the seat to the vehicle. Some attachment methods using bolts, for example, can introduce significant strain in the seat supporting structure. Some compliance therefore must be introduced into the seat structure to reduce these attachment induced stresses to a minimum. Too much compliance, on the other hand, can significantly weaken the seat structure and thereby potentially cause a safety issue. This problem can be solved by rendering the compliance section of the seat structure highly nonlinear or significantly limiting the range of the compliance. One of the support members, for example, can be attached to the top of the seat structure through the use of the pinned joint wherein the angular rotation of the joint is severely limited. Methods will now be obvious to those skilled in the art to eliminate the attachment induced stress and strain in the structure which can cause inaccuracies in the strain measuring system.

In the examples illustrated above, strain measuring elements have been shown at each of the support members. This of course is necessary if an accurate measurement of the weight of the occupying item of the seat is to be determined. For this case, typically a single value is inputted into the neural network representing weight. Experiments have shown, however, for the four strain gage transducer system, that most of the weight and thus most of the strain occurs in the strain elements mounted on the rear seat support structural members. In fact, about 85 percent of the load is typically carried by the rear supports. Little accuracy is lost therefore if the forward strain measuring elements are

eliminated. Similarly, for most cases, the two rear mounted support strain elements measure approximately the same strain. Thus, the information represented by the strain in one rear seat support is sufficient to provide a reasonably accurate measurement of the weight of the occupying item of the seat.

If a system consisting of eight transducers is considered, four ultrasonic transducers and four weight transducers, and if cost considerations require the choice of a smaller total number of transducers, which of the eight transducers should be eliminated? Fortunately, the neural network technology provides a technique for determining which of the eight transducers is most important, which is next most important, etc. If the six most critical transducers are chosen, that is the six transducers which contain the most useful information as determined by the neural network, and a neural network can be trained using data from those six transducers and the overall accuracy of the system can be determined. Experience has determined, for example, that typically there is almost no loss in accuracy by eliminating two of the eight transducers, that is two of the strain gage weight sensors. A slight loss of accuracy occurs when one of the ultrasonic transducers is then eliminated.

This same technique can be used with the additional transducers described above. A transducer space can be determined with perhaps twenty different transducers comprised of ultrasonic, optical, electromagnetic, motion, heartbeat, weight, seat track, seatbelt payout, seatback angle etc, transducers. The neural network can then be used in conjunction with a cost function to determine the cost of system accuracy. In this manner, the optimum combination of any system cost and accuracy level can be determined.

In many situations where the four strain measuring weight sensors are applied to the vehicle seat structure, the distribution of the weight among the four strain gage sensors, for example, well very significantly depending on the position of the seat in the vehicle and particularly the fore and aft and secondarily the seatback angle position. A significant improvement to the accuracy of the strain gage weight sensors, particularly if less than four such sensors are used, can result by using information from a seat track position and/or a seatback angle sensor. In many vehicles, such sensors already exist and therefore the incorporation of this information results in little additional cost to the system and results in significant improvements in the accuracy of the weight sensors.

There have been attempts to use seat weight sensors to determine the load distribution of the occupying item and thereby reach a conclusion about the state of seat occupancy. For example, if a forward facing human is out of position, the weight distribution on the seat will be different than if the occupant is in position. Similarly a rear facing child seat will have a different weight distribution than a forward facing child seat. This information is useful for determining the seated state of the occupying item under static or slowly changing conditions. For example, even when the vehicle is traveling on moderately rough roads, a long term averaging or filtering technique can be used to determine the total weight and weight distribution of the occupying item. Thus, this information can be useful in differentiating between a forward facing and rear facing child seat.

It is much less useful however for the case of a forward facing human or forward facing child seat that becomes out of position during a crash. Panic braking prior to a crash, particularly on a rough road surface, will cause dramatic fluctuations in the output of the strain sensing elements. Filtering algorithms, which require a significant time slice of

data, will also not be particularly useful. A neural network or other pattern recognition system, however, can be trained to recognize such situations and provide useful information to improve system accuracy.

Other dynamical techniques can also provide useful information especially if combined with data from the vehicle crash accelerometer. By studying the average weight over a few cycles, as measured by each transducer independently, a determination can be made that the weight distribution is changing. Depending on the magnitude of the change a determination can be made as to whether the occupant is being restrained by a seatbelt. It a seatbelt restraint is not being used, the output from the crash accelerometer can be used to accurately project the position of the occupant during pre crash braking and eventually the impact itself providing his or her initial position is known.

In this manner, a weight sensor with provides weight distribution information can provide useful information to improve the accuracy of the occupant position sensing system for dynamic out of position determination. Naturally, even without the weight sensor information, the use of the vehicle crash sensor data in conjunction with any means of determining the belted state of the occupant will dramatically improve the dynamic determination of the position of a vehicle occupant.

Although several preferred embodiments are illustrated and described above, there are other possible combinations using different sensors which measure either the same or different morphological characteristics, such as knee position, of an occupant to accomplish the same or similar goals as those described herein. There are also numerous additional applications in addition to those described above. This invention is not limited to the above embodiments and should be determined by the following claims.

It should be mentioned that the adjustment system may be used in conjunction with each vehicle seat. In this case, if a seat is determined to be unoccupied, then the processor means may be designed to adjust the seat for the benefit of other occupants, i.e., if a front passenger side seat is unoccupied but the rear passenger side seat is occupied, then adjustment system might adjust the front seat for the benefit of the rear-seated passenger, e.g., move the seat base forward.

In one weight measuring method in accordance with the invention, at least one strain gage transducer is mounted at a respective location on the support structure and provides a measurement of the strain of the support structure at that location, and the weight of the occupying item of the seat is determined based on the strain of the support structure measured by the strain gage transducer(s). In another method, the seat includes the slide mechanisms for mounting the seat to a substrate and bolts for mounting the seat to the slide mechanisms, the pressure exerted on the seat is measured by at least one pressure sensor arranged between one of the slide mechanisms and the seat. Each pressure sensor typically comprises first and second layers of shock absorbing material spaced from one another and a pressure sensitive material interposed between the first and second layers of shock absorbing material. The weight of the occupying item of the seat is determined based on the pressure measured by the at least one pressure sensor. In still another method for measuring the weight of an occupying item of a seat, a load cell is mounted between the seat and a substrate on which the seat is supported. The load cell includes a member and a strain gage arranged thereon to measure tensile strain therein caused by weight of an occupying item of the seat. The weight of the occupying item of the seat is determined based on the strain in the member measured by the strain gage. Naturally, the load cell can be incorporated at other locations in the seat support structure and need not be between the seat and substrate. In such a case, however, the seat would need to be especially designed for that particular mounting location. The seat would then become the weight measuring device.

Furthermore although the weight measuring system and apparatus described above are described for particular use in a vehicle, it is of course possible to apply the same constructions to measure the weight of an occupying item on other seats in non-vehicular applications, if a weight measurement is desired for some purpose.

Although several preferred embodiments are illustrated and described above, there are possible combinations using other geometries, sensors, materials and different dimensions for the components that perform the same functions. This invention is not limited to the above embodiments and should be determined by the following claims. For example, the weight measuring apparatus and methods described above could be used in conjunction with a seat position sensor to provide for an accurate determination of the identification and location of the occupying item of the seat.

What is claimed is:

1. A seat for a vehicle, comprising

a seat cushion assembly and seat back assembly defining a contact surface adapted to be in contact with an occupying, item of the seat,

a support structure arranged underneath said seat cushion assembly and adapted to support said seat cushion assembly and said seat back assembly on a substrate in the vehicle, said support structure being structured and arranged to transfer a force exerted by the occupying item on said support structure to the substrate,

at least one strain gage transducer, each of said at least one strain gage transducer being mounted at a respective location on said support structure arranged to provide a measurement of the strain of said support structure at the location at which said strain gage transducer is mounted, and

a control system coupled to said at least one strain gage transducer for determining the weight of the occupying item of the seat based on the strain of said support structure measured by said at least one strain gage transducer.

2. The seat of claim **1**, wherein the substrate is a floor of a motor vehicle.

3. The seat of claim **1**, further comprising electrical connection means for connecting said at least one strain gage transducer to said control system.

4. The seat of claim **1**, wherein said at least one strain gage transducer comprises a plurality of strain gage transducers.

5. The seat of claim **4**, wherein at least one of said transducers includes a strain gage element and signal conditioning electronics arranged adjacent thereto.

6. The seat of claim **1**, wherein each of said at least one strain gage includes signal conditioning circuitry and an analog to digital converter such that the measured strain is output as a digital signal.

7. The seat of claim **1**, wherein said support structure comprises two elongate slide mechanisms adapted to be mounted on the substrate and support members for coupling the seat to said slide mechanisms, said at least one strain gage transducer comprising a plurality of strain gage transducers, one of said strain gage transducers being arranged on at least one of said support members.

8. The seat of claim **7**, wherein said support structure further comprises a slide member, one of said strain gage transducers being mounted on said slide member.

9. The seat of claim 7, further comprising means for increasing the accuracy of said strain gage transducers.

10. The seat of claim 9, wherein said means for increasing the accuracy of said strain gage transducers comprises at least one of said support members comprising first and second structural members having longitudinally opposed ends and a third structural member overlying the opposed ends of said first and second structural members and being connected to said first and second structural members, one of said strain gage transducers being arranged on said third structural member.

11. The seat of claim 9, wherein said means for increasing the accuracy of said strain gage transducers comprises at least one of said support members being a tube having a first section adjacent the seat having a first diameter, a second section adjacent a respective one of said slide mechanisms having the same diameter as said first section and a third section between said first and second section having a second diameter less than the first diameter, one of said strain gage transducers being mounted on said third section of said tube.

12. The seat of claim 9, wherein said means for increasing the accuracy of said strain gage transducers comprises at least one of said support members comprising a tube having a hole therein, one of said strain gage transducers being arranged adjacent said hole.

13. The seat of claim 7, wherein said support members each comprise an angled structure for connecting a respective side of the seat to a respective one of said slide mechanisms.

14. The seat of claim 13, wherein said support members each further comprise a gusset to bridge an angle of said structure, said strain gage transducers being arranged on said gussets.

15. The seat of claim 1, further comprising a transverse support member extending between opposed lateral sides of the seat and below said cushion assembly, said at least one transducer being arranged on said transverse support member.

16. An adjustment system for adjusting a component of a vehicle based on occupancy of a seat, comprising:

at least one wave sensor for receiving waves from an area of the seat in the passenger compartment and generating an output representative of waves received by said at least one wave sensor;

the seat of claim 1, said control system being arranged to generate an output representative of the measured weight applied onto the seat;

adjustment means arranged in connection with the component for adjusting the component, and

processor means for receiving the outputs from said at least one wave sensor and said control system and evaluating the seated-state of the seat based thereon and based at least on the evaluation of the seated-state of the seat, directing said adjustment means to adjust the component.

17. A seat for a vehicle, comprising

a cushion assembly defining a contact surface adapted to be in contact with an occupying item,

slide mechanisms for supporting said cushion assembly on a substrate,

bolts for mounting said cushion assembly to said slide mechanisms,

at least one pressure sensor arranged underneath said cushion assembly and between one of said slide mechanisms and said cushion assembly for measuring pressure exerted on said cushion assembly, each of said at least one pressure sensor comprising first and second washers and a compressible material arranged between said first and second washers to thereby form a sandwich of said first and second washers and said compressible material, each of said at least one pressure sensor further comprising an electrode on each side of said compressible material, said electrodes being spaced from one another by at least a thickness of said compressible material such that upon compression of said compressible material, the spacing between said electrodes is decreased and capacitance of said sandwich changes, and

a control system coupled to said electrodes for determining the weight of the occupying item of said cushion assembly based on the change in the capacitance of said sandwich.

18. The seat of claim 17, wherein said compressible material includes upper and lower faces and a respective one of said electrodes is arranged on each of said upper and lower faces.

19. An adjustment system for adjusting a component of a vehicle based on occupancy of a seat, comprising:

at least one wave sensor for receiving waves from an area of the seat in the passenger compartment and generating an output representative of the reflected waves received by said at least one wave sensor;

the seat of claim 17, said control system being arranged to generate an output representative of the measured weight applied onto the seat;

adjustment means arranged in connection with the component for adjusting the component, and

processor means for receiving the outputs from said at least one wave sensor and said control system and evaluating the seated-state of the seat based thereon and based at least on the evaluation of the seated-state of the seat, directing said adjustment means to adjust the component.

20. The system of claim 19 wherein the component is an airbag.

21. A seat for a vehicle, comprising

a cushion assembly defining a contact surface adapted to be in contact with an occupying item of the seat,

a support structure arranged underneath said cushion assembly and adapted to support said cushion assembly on a substrate in the vehicle,

a load cell connected to said support structure and adapted to be mounted to the substrate, said load cell including a member and a strain gage arranged on said member in such a position to measure strain in said member caused by weight of an occupying item of the seat, said strain gage including at least first and second strain sensing elements, said first strain sensing element being arranged in a longitudinal direction of said member and said second strain sensing element being arranged in a transverse direction of said member, and

a control system coupled to said load cell for determining the weight of the occupying item of the seat based on the strain in said member measured by said strain gage.

22. The seat of claim 21, wherein said member is a beam.

23. The seat of claim 21, wherein said member is a beam and said strain gage further includes third and fourth strain sensing elements, said third strain sensing element being arranged in the longitudinal direction of said beam and said fourth strain sensing element being arranged in the transverse direction of said beam.

24. The seat of claim 21, wherein said member is a beam including a hole in an upper surface, said strain gage being situated in said hole.

25. The seat of claim 21, wherein said member is a tube, at least one of said strain sensing elements being arranged on said tube to measure compressive strain in said tube and at least one of said strain sensing element being arranged on said tube to measure tensile strain in said tube.

26. The seat of claim 25, wherein said load cell further comprises a bolt for attaching said tube to said support structure and to the substrate.

27. The seat of claim 21, wherein said member is an elongate torsion bar, said torsion bar being adapted to be mounted at its ends to the substrate, said load cell further comprising a lever arranged between the ends of said torsion bar, said lever being connected to said cushion assembly such that a torque is imparted to said torsion bar upon weight being exerted on said cushion assembly.

28. The seat of claim 27, wherein said strain gage includes at least one torsional strain sensing element.

29. An adjustment system for adjusting a component of a vehicle based on occupancy of a seat, comprising:

at least one wave sensor for receiving waves from an area of the seat in the passenger compartment and generating an output representative of waves received by said at least one wave sensor;

the seat of claim 21, said control system being arranged to generate an output representative of the measured weight applied onto the seat;

adjustment means arranged in connection with the component for adjusting the component, and

processor means for receiving the outputs from said at least one wave sensor and said control system and evaluating the seated-state of the seat based thereon and based at least on the evaluation of the seated-state of the seat, directing said adjustment means to adjust the component.

30. An occupancy sensing system for a seat adapted to be mounted on a substrate, comprising

a cushion defining a contact surface adapted to be in contact with an occupying item,

a force sensing arrangement at least partially interposed between said cushion and the substrate for measuring the force transferred from said cushion to the substrate, and

a control system coupled to said force sensing arrangement for determining the weight applied by the occupying item onto said cushion based on the force being transferred from said cushion to the substrate measured by said force sensing arrangement.

31. The sensing system of claim 30, wherein said force sensing arrangement comprises

a support structure for connecting said cushion to the substrate.

32. The sensing system of claim 31, wherein said force sensing arrangement further comprises

at least one strain gage transducer arranged in connection with said support structure for measuring the force transferred from said cushion to the substrate passing through said support structure, said strain gage transducer providing a measurement of the strain of said support structure at the location at which said strain gage transducer is mounted.

33. An adjustment system for adjusting a component of a vehicle based on occupancy of a seat, comprising:

at least one wave sensor for receiving waves from an area of the seat in the passenger compartment and generating an output representative of waves received by said at least one wave sensor;

the sensing system of claim 30, said control system being arranged to generate an output representative of the weight applied onto said cushion;

adjustment means arranged in connection with the component for adjusting the component, and

processor means for receiving the outputs from said at least one wave sensor and said control system and evaluating the seated-state of the seat based thereon and based at least on the evaluation of the seated-state of the seat, directing said adjustment means to adjust the component.

34. An occupant position sensing arrangement for determining the location of an occupying item of a vehicle, comprising

a cushion defining a contact surface adapted to be in contact with an occupying item,

a force sensing arrangement at least partially interposed between said cushion and the substrate for measuring the force transferred from said cushion to the substrate at a plurality of locations,

at least one additional sensor system for measuring a characteristic of the occupying item or the seat, and

a processor coupled to said at least one additional sensor system and to said force sensing arrangement for determining the weight applied by the occupying item onto said cushion based on the force being transferred from said cushion to the substrate measured by said force sensing arrangement and the distribution of weight of the occupying item, said processor providing an indication of the location of the occupying item based at least in part on the distribution of weight of the occupying item and the measured characteristic of the occupying item.

35. The sensing arrangement of claim 34, wherein said force sensing arrangement comprises

a support structure for connecting said cushion to the substrate.

36. The sensing arrangement of claim 35, wherein said force sensing arrangement further comprises

at least one strain gage transducer arranged in connection with said support structure for measuring the force transferred from said cushion to the substrate passing through said support structure, said strain gage transducer providing a measurement of the strain of said support structure at the location at which said strain gage transducer is mounted.

37. The sensing arrangement of claim 34, further comprising

receiver means for receiving waves affected by the presence of the occupying item, said receiver means being coupled to said processor,

said processor means providing an indication of the location of the occupying item based at least in part on the distribution of weight of the occupying item, the measured characteristic of the occupying item and the waves received by said receiver means.

38. An aooaratus for mounting a seat on a substrate in a vehicle, comprising

a support structure comprising two elongate slide mechanisms adapted to be mounted on the substrate and support members for coupling the seat to said slide mechanisms, said support members each comprising an angled structure for connecting a respective side of the seat to a respective one of said slide mechanisms,

a plurality of strain gage transducers, each of said strain gage transducers being mounted at a respective location on said support structure and arranged to provide a measurement of the strain of said support structure at the location at which said strain gage transducer is mounted, one of said strain gage transducers being arranged on at least one of said support members, and

a control system coupled to said at least one strain gage transducer for determining the weight of the occupying item of the seat based on the strain of said support structure measured by said at least one strain gage transducer.

39. A seat for a vehicle, comprising

a cushion assembly defining a supporting surface for an occupying item of the seat,

a transverse support member extending between opposed lateral sides of said cushion assembly and below said cushion assembly,

at least one strain gage transducer arranged on said transverse support member to provide a measurement of the strain of said transverse support member at the location at which said at least one strain gage transducer is mounted, and

a control system coupled to said at least one strain gage transducer for determining the weight of the occupying item of the seat based on the strain of said transverse support member measured by said at least one strain gage transducer.

40. An apparatus for measuring the weight of an occupying item of a seat, comprising

a load cell adapted to be mounted to the seat and to a substrate on which the seat is supported, said load cell including an elongate torsion bar having first and second ends, a strain gage arranged on said torsion bar to measure strain in said torsion bar caused by weight of the occupying item of the seat and a lever arranged between said first and second ends of said torsion bar, said first and second ends of said torsion bar being adapted to be mounted to the substrate, said lever being adapted to be connected to the seat such that a torque is imparted to said torsion bar upon weight being exerted on the seat, and

a control system coupled to said load cell for determining the weight of the occupying item of the seat based on the strain in said torsion bar measured by said strain gage.

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